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Two-dimensional excitations of superfluid ^{4}He confined in 72% porosity xerogel

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Abstract

We present neutron inelastic-scattering measurements of the low-energy excitation spectrum of superfluid ^{4}He confined in porous xerogel glass. In addition to the bulk-like excitation, we also observe a broad peak centred at energies of less than that of the bulk-like peak. The dependence on filling fraction of both peaks has been investigated and we find that the second broad peak exhibits behaviour that is consistent with that of an excitation confined to the high-density liquid layers near the pore walls, i.e. with that of a two-dimensional excitation.

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Evidence of layer modes or two-dimensional excitations in superfluid ^{4}He has been seen when thin layers of the liquid are adsorbed onto the surfaces of various forms of graphite [1,2]. Recently, Dimeo et al. [3] showed that when superfluid ^{4}He fills the pores of vycor glass (porosity 30%) there is extra scattering below that of the roton, and that this scattering may be attributed to a two-dimensional roton. We present a continuation of this work, whereby superfluid ^{4}He was confined in porous xerogel glass (porosity 72%). In addition to the bulk-like roton excitation, an extra broad peak at an energy below that of the bulk-like excitation was observed. A preliminary analysis indicates that this peak behaves in a manner consistent with that of a two-dimensional excitation across the whole of the Q-range measured.

Measurements were made on the IN6 time-of-flight spectrometer at the Institut Laue-Langevin, Grenoble. Using a neutron wavelength of 4.6 Å, a Gaussian inelastic energy resolution of between 0.11 and 0.14 meV was attained. Measurements were performed of the empty glass, overfull-glass and at six filling fractions between 40 and 95%. The temperature was held constant at 1.25 K. The data were normalised to the beam monitor and corrected for variations in detector efficiency before being converted from time-of-flight and scattering angle to energy and momentum-transfer, respectively. Using the overfull-glass measurement, multiple-scattering corrections could be made to the data for filling fractions of 70% and greater. For filling fractions of less than this, the intensities of the peaks in the multiple scattering were a factor of 4 less than the statistical error bars, and hence multiple scattering corrections were not made for these filling fractions.

The evolution of the spectra with filling fraction is shown in Fig. 1 for $Q = 1.95\ \text{Å}^{-1}$. With a 40% filling fraction the spectra are featureless. With a 50% filling fraction a broad peak is seen at all Q-values. As a preliminary analysis, this peak was fitted by least squares to a

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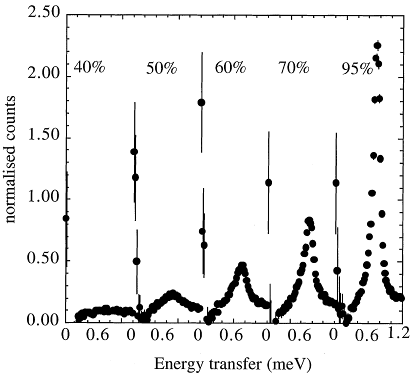

Fig. 1. Evolution of the spectra with filling fraction at a momentum transfer value of $Q = 1.95\ \text{Å}^{-1}$.

Gaussian function. The peak centres obtained reveal an excitation spectrum very similar in form to that of the bulk single quasi-particle excitation, but with slightly lower energies. With filling fractions of 60% and above, this broad peak remains with slightly shifted energies. Its intensity increases with filling fraction but saturates at a filling fraction corresponding to an atomic layer-coverage of about six layers. This is consistent with the layer-coverage dependence of the intensity of a two-dimensional excitation [1]. At the higher filling fractions a second peak grows with filling fraction out of the broad peak's high-energy side. This feature exhibits an energy dispersion curve that is almost identical to that of the bulk. Its intensity increases linearly with filling fraction, as is expected for a three-dimensional bulk-like excitation [1,2].

In summary, when superfluid ^{4}He is confined in porous xerogel glass, we show that in addition to the bulk-like excitation, there is evidence for the existence of two-dimensional layer-excitations at all wave-vectors studied. A detailed description of these measurements will be published elsewhere.

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References

[1] W. Thomlinson, J.A. Tarvin, L. Passal, Phys. Rev. Lett. 44 (1980) 266.
[2] B.E. Clements, H. Godfrin, E. Krotscheck, H.J. Lauter, P. Leiderer, V. Passiouk, C.J. Tymczak, Phys. Rev. B 53 (1996) 12242.
[3] R.M. Dimeo, P.E. Sokol, C.R. Anderson, W.G. Stirling, K.H. Andersen, M.A. Adams, Phys. Rev. Lett. 81 (1998) 5860.